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The Response of the QBO to Increases in CO2 Using Three Atmospheric Chemistry Configurations

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Long-term projections of the Quasi-Biennial Oscillation (QBO) remain highly uncertain. This is partly due to the paucity of models which are able to properly simulate that phenomenon. Only 5 of the 47 CMIP5 models are capable of spontaneously generating a realistic QBO (Butchart et al., 2018), and even those models exhibit large biases in key QBO characteristics (e.g. amplitude, period, vertical extent) when compared with observations. Furthermore, only 1 of these 5 employed interactive atmospheric chemistry, which is known to modulate QBO dynamics.

We here investigate the QBO response to increased greenhouse gases using the NASA Goddard Institute for Space Studies Middle Atmosphere Model E2.2. Compared to lower vertical resolution versions of Model E, version 2.2 has a higher model top (0.002 hPa), and additional interactive non-orographic gravity wave drag sources from convection and shear, which produce a sufficiently realistic QBO, thus rendering it suitable for use in climate change studies. Steady-state responses to doubled and quadrupled CO_2 from a pre-industrial control are analyzed, as well as the transient response to a 1% per year CO_2 increase. In addition, we systematically explore the impact of interactive chemistry in modulating the QBO response to increased CO_2 by contrasting interactive, prescribed, and linearized ozone chemistry configurations of the model. Overall, in response to increase CO_2 concentrations the QBO is seen to increase in frequency and weaken in amplitude, consistent with previous results, but the memory of the tropical stratosphere may complicate assessments of trends in chemistry and surface impacts. We also discuss implications for the trade-off between ensemble size and the complexity of the chemistry scheme in the model.